DOCUMENT RESUME

ED 307 784 EC 220 293

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TITLE Creating Scholar/Practitioner Networks for the Most Capable Youth in Mathematics, Science and Technology and Discussant Reactions.
PUB DATE Mar 88
NOTE 32p.; In: Dreyden, Julia I. Ed.; And Others. Developing Talent in Mathematics, Science and Technology: A Conference on Academic Talent (Durham, North Carolina, March 28-30, 1988); see EC 220 285.
PUB TYPE Speeches/Conference Papers (150) -- Reports - Descriptive (141) -- Viewpoints (120)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Academically Gifted; *Information Networks; Mathematics Education; *Science Education; Scientists; *Social Networks; Social Support Groups; Technological Literacy; *Theory Practice Relationship

ABSTRACT

Operational and organizational principles are suggested for guiding the establishment of networks to facilitate ongoing interactions between the practitioner and scholar communities in mathematics, science, and technology. These networks would define problems that need attention, carry out research on the problems, and incorporate the results of the research into educational and support programs for the most capable youth. The issue of recruiting talented students impacts on the creation of such networks. Statistical data are presented on graduate school enrollments, scores of science Ph.D.'s on the Scholastic Aptitude Test, and scores on the Graduate Record Examination. The Government-University-Industry Research Roundtable is presented as an example of a scholar-practitioner network, along with other examples such as the Agricultural Research System and Extension Service, Transportation Research Board, Mathematical Sciences Education Board, Ford Foundation Urban Mathematics Collaboratives, and the Yale-New Haven Teachers Institute. The paper concludes with a list of principles for creating scholar/practitioners networks. (JDD)

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CREATING SCHOLAR/PRACTITIONER NETWORKS FOR THE MOST CAPABLE YOUTH IN MATHEMATICS, SCIENCE AND TECHNOLOGY

Don I. Phillips

How can the results of research--in fields such as education, psychology, sociology, anthropology, and economics--serve to improve the practice of education? This question is of long-standing concern to the educational community, both scholar/researchers and teacher/practitioners. One solution often proposed is to establish more effective means for ongoing communication and greater mutual understanding between these two communities. My own direct experience with this topic is limited to a year I spent as an education policy fellow at the National Institute of Education over ten years ago--hardly a basis for my providing any enlightenment on the subject to the knowledgeable and experienced group gathered at this conference. What I have been doing for much of the past ten years is establishing procedures and institutions for collaboration, in both the conduct of research and the formulation of science and technology policy, among working scientists and engineers in universities and industry, academic administrators, industry officials, and federal and state program managers and policy officials. I assume, therefore, that the organizers of this conference felt that my experience with these types of networks would provide a basis for discussion of what would work best in creating scholar/practitioner networks to focus on issues related to the most capable youth in mathematics, science, and technology. I hope I can fulfill their expectations.

Other speakers will address problems in the identification, education, and nurturing of the most talented students and describe research pursuits that might help the practitioner community in carrying out these functions more effectively. I take my task to be the identification of operational and organizational principles that should guide the establishment of networks to facilitate ongoing interactions between the practitioner and scholar communities in defining the problems that need attention, in carrying out the research on the problems, and in incorporating the results of the research into educational and support programs for the most capable youth.

First, however, I will address one topic in the area of science and engineering talent that requires further examination and research. Then I will return to the topic of scholar/practitioner networks.

Nurturing Science and Engineering Talent

The Government-University-Industry Research Roundtable has identified the development, identification, recruitment, and retention of science and engineering talent as the most critical issue facing the scientific enterprise. Recently the Roundtable, along with other units in the Academy Complex, has been examining the adequacy of the flow of the most talented students into graduate school in the sciences, mathematics, and engineering. I will review the findings and areas for further study identified in this investigation since they seem most closely related to the topic of this conference.

While the main focus of the investigation was on the junction between undergraduate and graduate school, I will begin with a review of student choices

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of undergraduate major because decisions at this stage affect the ultimate flow of students into graduate school.

Using data from the Cooperative Institutional Research Program (CIRP) Solmon looked at:[2]

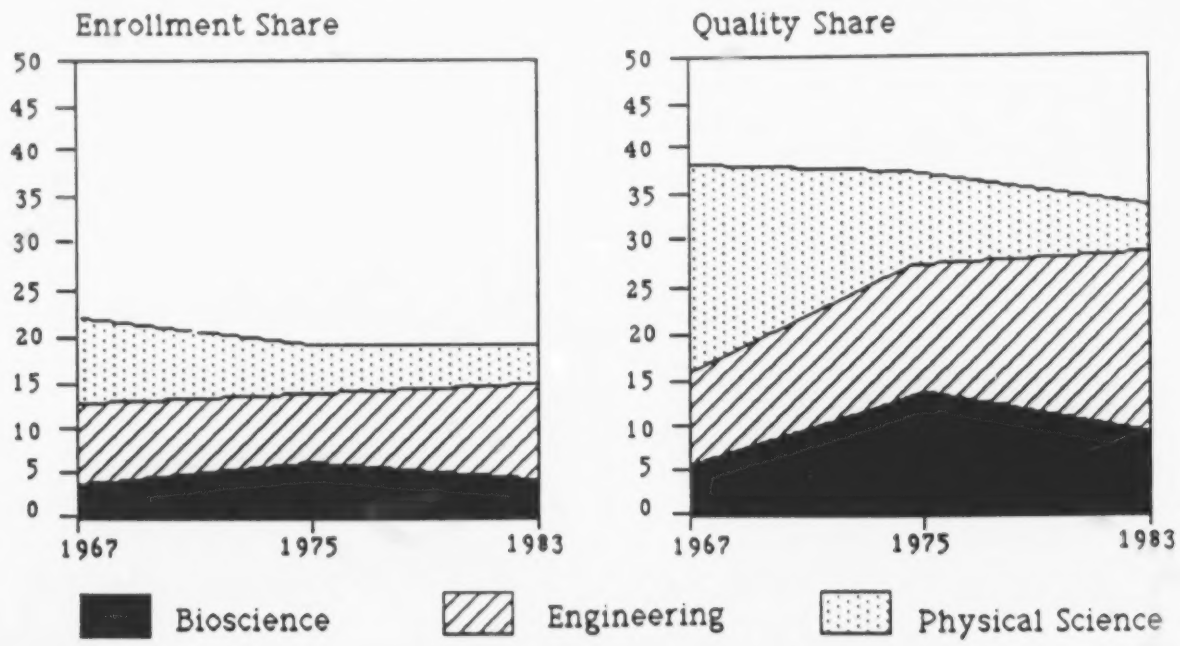
- The change in the share of all freshmen intending to major in a particular field. He calls this the "Enrollment Share" (ES).
- The change in the share of "smart" freshmen intending to major in various fields. He calls this the "Quality Share" (QS). A very restrictive definition of smart was used: 1) A/A+ high school average, 2) accepted to all schools to which they applied, 3) aspirations to more than a bachelor's degree *and* 4) expectations of graduating with honors.

Between 1967 and 1985, the shares of all students and smart students intending to major in science and engineering changed as shown below in Figure 1. The data are included in Attachment I.

At the undergraduate level, science, mathematics, and engineering combined continue to have a strong attraction for the very bright students. There have been shifts, however, among the fields. In the biological sciences both enrollment and quality went up temporarily and returned to near former levels. Engineering is attracting more and better students, and the quality share increased even faster than the enrollment share. The quality share and enrollment share in the physical sciences maintain about the same ratio, but the sharp decline in interest in the physical sciences means that fewer smart students are entering this field.

Figure 1

Choices of Undergraduate Major 1967-1983



In Attachment II data compiled by Holstrom are summarized which add to Solomon's findings that significant proportions of the brightest students continue to major in mathematics, science, and engineering at the undergraduate level. Three sets of data are included in the attachment: 1) the change between 1981 and 1985 in the percent of freshmen intending to major in various science and engineering disciplines who had A+/A/A- high school grade average, 2) the percent of students who graduated in various science and engineering majors who were top students (those in the 1981 freshman cohort who earned B+ or better averages in 1985), and 3) persistence rates by field and field switching patterns of students with A averages at the time of receipt of the bachelor's degree.

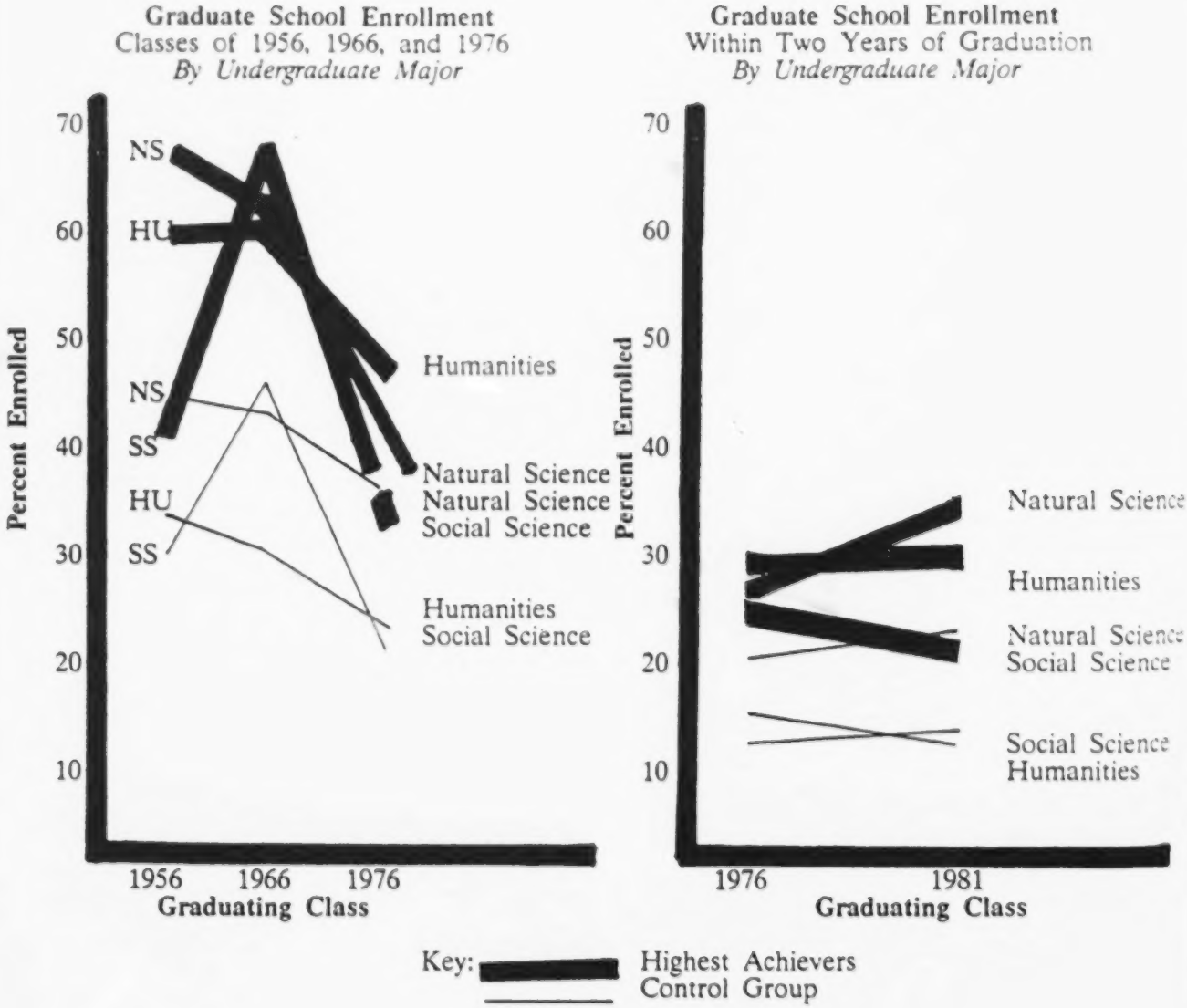
At the graduate level, the data are limited; we could find only three relevant studies.

- Figure 2 summarizes the findings by Goldberg and Koenigsknecht[3] in their study of the post-baccalaureate enrollment of the "highest achievers," i.e., students among the top 3% to 5% of their graduating classes of the COFHE (Consortium on Financing Higher Education) institutions--eleven private and three public institutions. The figure shows that between 1966 and 1976, the highest achieving undergraduates increasingly chose professional school over graduate school and that there was a sharp decline in the highest achievers in the natural sciences going on to graduate school. Between 1976 and 1981, the proportions were level or increased slightly.

- Hartnett had looked at the SAT and ACT scores of people who earned doctorate and professional degrees between 1966 and 1981. Figure 3 shows that the proportion that scored 750 or higher on the SAT mathematics test rose in each of the four science fields. This study asks: of all students who received Ph.D. degrees, what proportion were high achievers in high school? Thus, we do not get a sense of the fraction of the superior students who never went on to graduate school in the sciences.

- Table 1 shows the GRE scores of students planning to enter graduate programs in the sciences, mathematics and engineering. ETS does not have data prior to 1980 so unfortunately only recent data points are possible. The data show that while the absolute number of top scores is up in every field, the increases in the biological and physical sciences are not as high as the overall increases in the number of top scores. Thus, the share of top scorers attracted to these fields is down. Conversely, in the mathematical and engineering sciences the increases in the number of top scores are above the general rate, giving those fields increased shares.

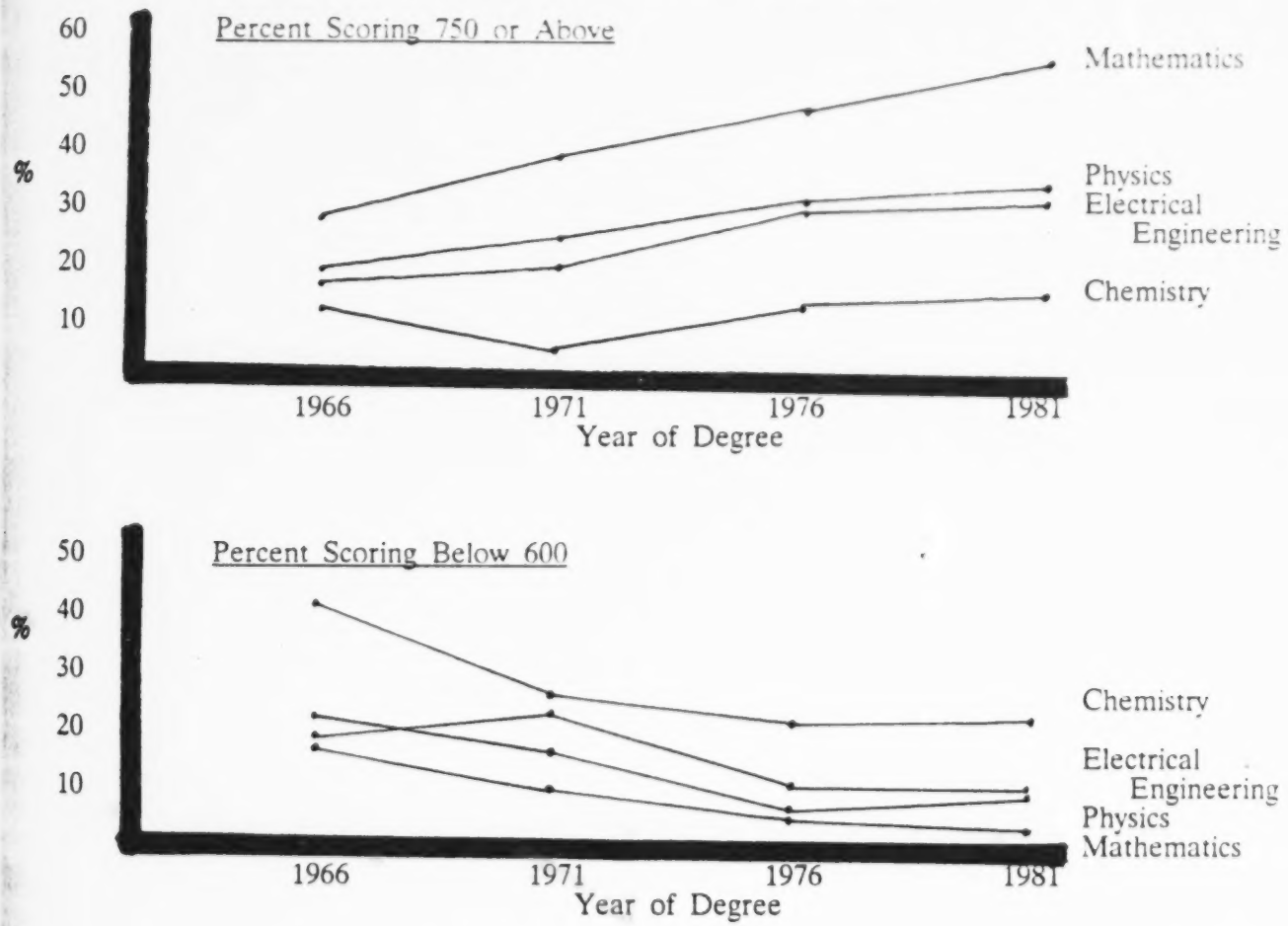
Figure 2



Source: Goldberg and Koenigsknecht. **Highest Achievers**. Northwestern University, 1985.

Figure 3

Percentage of Science Ph.D.'s Scoring Above 750 (Top) and Below 600 (Bottom) on the SAT-M, by Year of Doctorate



N for SAT-M

	1966	1971	1976	1981
Math	53	129	125	87
Physics	124	226	238	212
Electrical Engineering	49	110	96	94
Chemistry	163	355	373	...

Source: Hartnett, Rodney T., "Has There Been a Graduate Student 'Brain Drain' in the Arts and Sciences?"

TABLE 1
TABULATIONS OF ETS DATA ON GRE SCORES/TEST-TAKERS

	Quantitative			Verbal	
	1981/82	1986/87	Percent change	1981/82	1986/87
All U.S. Citizen GRE Test-Takers	157,810	180,866	+15%	157,810	180,866
Number scoring 750+ (top scorers)	6,057	10,630	+75%	2,705	3,518
Percent of top scorers	3.8%	5.9%	-	1.7%	1.9%
Physical, Biological Mathematical and Engineering (PBM&E) Sciences					
Total Number of test takers expecting to enroll in PBM&E	30,087	36,010	+20%	30,087	36,010
Number of PBM&E test takers with top scores	3,900	6,891	+77	643	786
PBM&E top scorers as percent of all PBM&E test-takers	13.0%	19.1%	-	2.1%	2.2%
PBM&E top scorers as share of all top scorers	64.4%	64.8%	-	23.8%	22.3%
Physical Sciences (PS)					
Number of test takers	6,930	6,265	-10%	-	-
Mean GRE score	623.5	641.5	-	-	-
Number scoring 750+	844	1,151	+36%	-	-
PS top scorers as percent of all PS	12.2%	18.4%	-	-	-
PS top scorers as share of all top scorers	13.9%	10.8%	-	-	-

	QUANTITATIVE		
	1981/82	**1986/87**	**Percent change**
Biological Sciences (BS)			
Number of test takers	9,167	8,327	-9%
Mean GRE score	572.2	575.9	-
Number scoring 750+	345	514	+49%
BS top scorers as percent of all BS	3.8%	6.2%	-
BS top scorers as share of all top scorers	5.7%	4.8%	-
Mathematical Sciences (MS)			
Number of test takers	5,921	8,853	+50%
Mean GRE score	646.8	657	-
Number scoring 750+	1,101	2,021	+84%
MS top scorers as percent of all Mathematics	18.6%	22.8%	-
MS top scorers as share of all top scorers	18.2%	19.0%	-
Engineering Sciences (ES)			
Number of test takers	8,069	12,565	+56%
Mean GRE score	668.6	676.4	-
Number scoring 750+	1,610	3,205	+99%
ES top scorers as percent of all ES	20.0%	25.5%	-
ES top scorers as share of all top scorers	26.6%	30.2%	-

Source: Government-University-Industry Research Roundtable, unpublished working papers.

The data provide only a limited understanding of the adequacy of the flow of top students into science, mathematics, and engineering graduate programs. While the results of these studies do not demonstrate the existence of a problem, neither do they provide a sufficient basis for feeling sanguine about the situation. Anecdotal evidence in the form of testimony by university faculty points to signs of trouble, and there are additional causes for concern.

- The declining interest of top U. S. undergraduates in the physical sciences is worrisome.

- The movement of top students from the physical sciences to engineering is part of the more general movement of students toward utilitarian degrees. However, there are deeper implications here than simple field preference because, although engineering education is more "scientific" than it used to be, engineering students are less likely to go on to graduate school than those in the physical sciences. This has potential impact on the quality of the research work force.

- Demographic trends are well known and disturbing. The number of twenty-two year olds is projected to drop more than 25 percent before the end of this century, and already fewer U. S. students with bachelors degrees in the natural sciences and engineering are electing to continue on for Ph.Ds. Increased female and minority participation could raise overall degree attainment rates, but achieving this at a significant level will be difficult.

- Major losses to the science and engineering talent pool occur during the college years and in the transition from undergraduate to graduate school. By college graduation, only 35 percent of the high school seniors who planned on mathematics, science, and engineering majors have stayed with their plans. Over 80 percent of mathematics, science, and engineering baccalaureates have never started or have left graduate school within three years of college graduation. The scientific community has long assumed that the students with the best scientific minds generally will pursue science as a career; that they will be disproportionately represented among those who persist through college and graduate school, and that their passion for science will override any disincentives through such factors as the availability of jobs, income potential, job security, and occupational status. There is reason to believe now, however, that the best students are influenced by the same economic incentives and the same push and pull of opportunity that moderate the flow of scientific talent generally; that is, that the stability and level of support for research projects and the comparative value of salaries, for example, will attract or discourage the smartest students right along with the merely good ones.

Scientific breakthroughs and technological advance depend on the work of the brightest and most creative minds. Yet we know little about the flow of these students into research training programs and about the factors that influence their decisions. The impact of demographics on supply alone indicates that the competition among government, industry, and universities for these most talented

students will become increasingly intense over the next decades, and that the time, effort, and money required to attract, nurture, and retain an adequate share in science and engineering talent, as some predict, will exacerbate the challenges. To be successful in this competition, we need to know more about this cadre of college students than we do currently. This is a topic for further research and an area in which the research findings need to be incorporated into educational practice.

The Roundtable will continue to work in this area; I am interested in your suggestions of important questions to investigate. The work will involve a mix of scholars, college faculty and administrators, policy-makers, and students. This is typical of the cross-section of people that participate in Roundtable activities, and therefore our structure and operating procedures are relevant to the creation of scholar/practitioner networks.

The Government-University-Industry Research Roundtable

The Government-University-Industry Research Roundtable (GUIRR) was established in 1984 as an alternative to the traditional study commission approach to science and technology policy issues. It is sponsored by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. Two unique features characterize the Roundtable.

First, the Roundtable was created on the assumption that all sectors--government, universities, and industry--share the responsibility for the stewardship of the scientific and engineering enterprise and for ensuring its continued contributions to the national well-being. Both the structure and the operation of the Roundtable are based on this premise. The Roundtable Council, the guiding body for the organization, includes senior federal R & D officials, senior officials from academia and industry, and working academic scientists and engineers. The members of the Council are listed in Attachment III.

The second unique feature of the Roundtable is its ongoing nature. It is not a group convened to study an issue, write a report, disband and go home. The Roundtable is a means for addressing the important issues within a structure that provides for continuity and follow-up. This is the first time that all the parties have sat down together in an organized manner and on a continuing basis to examine the critical problems and opportunities facing American science and engineering.

The purpose of the Roundtable is to try to understand issues, to inject imaginative thought into the system, and to provide a setting for the seeking of common ground. The Roundtable is a forum in which all the parties work together through the Council to define an agenda and to examine the topics selected. The Roundtable is not an organizational unit that outside groups commission to undertake specific studies nor is the Roundtable a group that designs studies for specific clients.

The initial results of this experiment of a new approach to science and technology policy issues are encouraging. The Roundtable has established a

tradition for convening principals from all sectors on a regular basis, and it is recognized by agencies and organizations of federal and state governments, universities, and industry as being effective in stimulating new ideas and actions within the R&D enterprise. Furthermore, assuming there is credence to the adage, "imitation is the highest form of flattery," it is noteworthy that the Roundtable has served as a model for the design of three similar organizations within the Academy Complex to address three different areas--the Manufacturing Forum, the Forum on Drug Development and Regulation, and the National Forum on the Future of Children and Their Families.

Several features of the Roundtable structure and operation have been essential to its initial success. They are summarized below:

1. *Sponsorship.* The sponsorship of the Roundtable by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine provides a natural setting with credibility among all elements of the research community in the three sectors.

2. *Roundtable Council.* The senior federal R&D officials and top industry officers are full and active participants on the Council. Their contributions and leadership have been essential to the accomplishments of the Roundtable.

3. *Working Groups.* The Research Roundtable identifies and examines issues through working groups. Once the groups have elucidated the central issues for the topics selected, identified the problems and opportunities, and considered options for dealing with them, they bring their observations and conclusions back to the Council for further discussion. This combination of study and analysis in the working groups by operational-level representatives from all sectors and discussion in the Council by policy-level representatives from all sectors has produced an environment that leads to the introduction of new ideas and new procedures into the system.

4. *Balanced Views.* The Roundtable has established a reputation for working effectively with all sectors while maintaining neutrality and objectivity. All points of view are presented in Roundtable deliberations. The Roundtable has avoided becoming a proponent for the views of any one constituency. The focus of Roundtable deliberations has been: what is best for the national interest?

5. *Long-term vs. Short-term Issues.* The Roundtable has achieved a workable balance between the attention to broad, ongoing concerns of the research community (for example, nurturing science and engineering talent, financing the university infrastructure, and enchancing university-industry interactions) and to the search for solutions to immediate problems (for example, streamlining administrative procedures for government-sponsored university research and for industry-sponsored university research, assessing the effectiveness of state government science and technology programs, and operating multidisciplinary research and education programs in universities).

6. *Flexible Financial Support.* Support for the Roundtable has been provided by the National Research Council; the Sloan and Mellon Foundations; the Departments of Agriculture, Defense, and Energy; the National Institutes of Health;

the National Science Foundation; the Monsanto Company; and the Pennsylvania Ben Franklin Partnership Program. The majority of these funds is provided as general support for the Roundtable, enabling the Roundtable to respond quickly to problems and opportunities as they arise and to address issues in flexible, diverse, and innovative ways.

7. *Personalities.* The Roundtable is foremost a process--a process for bringing together the diverse constituencies concerned with the research enterprise for common purpose. As such, it is an intensely personal enterprise, whose effectiveness has depended on the ability of Dale Corson, the first Roundtable chairman, James Ebert, the current Roundtable chairman, the Council, the working groups, and the staff to work constructively together and with the full range of relevant constituency groups and individuals. The ability of the Roundtable to stimulate constructive change in the system depends on the "delicacy" and the balance with which it is able to address issues that are typically complex, intractable, emotional, and controversial.

Additional Examples of Scholar/Practitioner Networks

I have selected five additional scholar/practitioner networks for consideration: two are national networks outside the field of education; one is a national network within education, and two are education networks at the local level. I conclude by proposing for discussion a list of principles for establishing and operating scholar/practitioner networks based on these examples and on the description of the Government-University-Industry Research Roundtable.

Before turning to the examples, it is helpful to consider the question, "What are the obstacles to scholar/practitioner networks, both generally and within the field of education?" The answers to this question are useful guides to identifying the essential characteristics of successful networks. Within any field of endeavor, scholars and practitioners have difficulty working together because of differences in intellectual milieu, values, reward systems, goals and objectives, and time scale. Successful networks find procedures, organizational structures, and operating personnel to minimize these differences.

Turning to the field of education in particular, we note sharp contrasts between scholars, principally in universities, and practitioners, principally in K-12 education, in the following areas: the prestige attributed to teachers at each level; the power of teachers as compared to administrators within each setting; the extent to which a scholar and a practitioner are considered as a contributor to the knowledge of a subject; how well it is thought a subject must be mastered by a scholar and by a practitioner. Scholars tend not to respect teachers and do not consider them as full-fledged members of their disciplinary professional societies. In addition, teachers tend to be isolated, have inadequate opportunities to renew their professional knowledge, have a limited role in developing curricula and school policies and practices, are skeptical of the relevance of scholarly activity and of the sincerity of scholars to the everyday challenges they face, and are disillusioned by the unsuccessful, on-again off-again efforts of the past aimed at improving school practices and linking the school community with the scholarly community. One teacher has commented, "Teachers are used to seeing something go for one

year and then dropped. I've been in four or five of those projects myself and it is a disaster [when they are cancelled]." Overcoming these obstacles is difficult. As some of the examples below illustrate, however, it can be done.

Agricultural Research System and Extension Service. The venerable and perhaps over-used example of an effective scholar/practitioner network is the agricultural research system and extension service. The central features of the system include:

- A national and regional research system financed principally by the federal government with research priorities focused on national and regional problems.

- A state-centered research system financed by state and federal governments, with the states being the larger funder, and with research priorities established principally to focus on state and local problems with substantial input into these priorities from state and local agricultural practitioners.

- A local county-based extension service to serve as a linkage between the state, regional, and national research enterprise and the local farmer. These county agents are the linchpin in bridging the scholarly and practitioner cultures in agriculture.

While there is plenty of criticism of the agricultural system as it struggles to adjust to current times, its overall success is unquestioned. What is questioned is the relevance of the agricultural research system and extension service to the educational system. The agricultural system is designed to meet the needs of the individual farmer. The farmer in turn has an economic incentive to learn of the latest scientific advances and has control over whether and how he uses this knowledge. In education, it is not sufficient to share new knowledge and demonstrate new practices with a teacher. The teacher is imbedded in a system of complex layered organizations that must be mobilized if new practices are to be implemented. In addition, other than personal motivation the teacher has had minimal if any incentives to pursue change in educational practice; there are attempts to change this situation now.

Transportation Research Board. The Transportation Research Board (TRB) is a unit of the National Research Council, which is the operating arm of the National Academy of Sciences and the National Academy of Engineering. The predecessors to TRB were established in 1920, TRB was established in 1974 with the purpose to advance knowledge concerning the nature and performance of transportation systems by stimulating research and disseminating the information derived therefrom. TRB is sponsored by the state highway or transportation departments, the Federal Highway Administration, the Federal Aviation Administration, the Urban Mass Transportation Administration, and the Association of American Railroads. About 35 percent of its support comes from the state highway and transportation departments; about 39 percent comes from federal government agencies; and the remainder comes from other associations, publication sales, etc. Through a broad range of technical activities, meetings, publications, and field visits, all of which are interrelated through an organizational structure

operated by the TRB, there is a high level of communication, research priority setting, research program operation, and sharing of research results among local, state and federal transportation practitioners and the transportation research community. TRB is recognized as the agency that reports the useful results from the nation's transportation research, and it is also a focal point for convening the practitioner community. Productive interaction between the two communities is the result.

The Mathematical Sciences Education Board. The concept of the Mathematical Sciences Education Board (MSEB) was brought to the National Research Council by the mathematics community. In part, it is modeled after the Transportation Research Board--a focal point at the national level for linkage among researchers, practitioners, administrators, and policy-makers, for the development of programs, practices and policies that must be implemented at the state and local levels.

In 1985, the National Research Council established the Mathematical Sciences Education Board. This Board is designed to become the most comprehensive and far-reaching national leadership effort in mathematics education ever to be undertaken in the U. S. The goal is a systematic, nationwide, transformation of school mathematics. MSEB is still relatively young, but let me review some of its central features:

- The Board has representatives of all the stake-holders in the educational enterprise, including state government officials, school teachers and administrators, representatives from school boards, the PTA, both the mathematics education and the mathematics research organizations, and senior officers from some of the nation's leading companies. Professors and administrators from the country's most prestigious universities sit on the Board alongside teachers who face children in the classroom every day.

- MSEB will engage teachers, state and local education agencies, together with research mathematicians and officials from industry in processes of discussion, coordination, and the development of complimentary projects. The output of MSEB will not be pronouncements from "on high," but will be statements of common understanding among these communities.

- The MSEB is developing a working relationship with the National Center for Research in Mathematical Sciences Education at the University of Wisconsin and through this relationship will provide a linkage between the research and practitioner communities. MSEB also has an ongoing working relationship with the National Council of Teachers of Mathematics, as well as with the major organizations of research mathematicians.

Ford Foundation Urban Mathematics Collaboratives. In 1985, the Ford Foundation launched an experimental program to strengthen mathematics education in inner-city high schools. The Foundation has established eleven math collaboratives. The collaboratives will receive Foundation support for three to five years before becoming completely self-sustaining programs.

An urban mathematics collaborative typically consists of a community advisory board that includes teachers, school administrators, and leaders from business and higher education; a series of subcommittees that oversee specific collaborative functions; and a part-time administrative staff. The goal is to involve virtually all of the city's high school mathematics teachers in a diverse set of school-year and summer activities, jointly designed and operated by teachers and mathematicians from educational, cultural, and business institutions. Specific collaborative activities include industrial internships, exchange programs with colleges and industries, evening symposia, newsletters, and summer workshops. By fostering colleagueship among mathematicians from all sectors and increasing the human and financial resources available to teachers, the projects seek to reduce teachers' isolation, to boost their professional enthusiasm, to enhance both their receptivity to new ideas and their capacity to discriminate among them, and to encourage resourcefulness in their teaching. Central features of the program include:

- External support from a leading foundation to catalyze the program and mobilize a broad coalition of community resources.

- An ongoing programmatic focal point was created. The Education Development Center in Newton, Massachusetts, serves as an information and resources center to provide the collaboratives with information about mathematics and mathematics education, help them plan and implement their individual programs, and facilitate communication among the various projects.

- Each of the eleven projects is different, and builds on local strengths, local prestigious institutions, local influential individuals, and involves local financial resources.

- The local collaboratives project a sense of continuity; teachers are developing confidence that the collaborative is "here to stay."

- Summer institutes, mini-grant programs for innovative projects, and teacher resource centers all are structured to increase the professional self-esteem and horizons of the participating math teachers. Linkages with practicing mathematicians and research mathematicians are a part of these activities.

- Teacher advisory boards are an effective approach to placing teachers in leadership roles within the collaboratives.

The Yale-New Haven Teachers Institute. The Yale-New Haven Teachers Institute was established in 1978 as a joint program of Yale University and the New Haven public schools. Each year about eighty New Haven school teachers become fellows of the Institute to participate in seminars with Yale Faculty members. The seminars have two related, and equally important, purposes: general study of the seminar subject, and research and writing on individual curriculum units. In this way, curriculum development is integrated with intellectual renewal for teachers.

Four principles guide the program and constitute much of its distinctiveness: 1) the belief in the fundamental importance of the classroom teacher and of teacher-developed materials for effective learning; 2) the insistence that teachers of students at different levels interact as colleagues, addressing the common problems of teaching their disciplines; 3) the conviction that any effort to improve teaching must be teacher-centered and the consequent dependence on the Institute coordinators, who are teachers in each school, who meet weekly with the director and who constitute an essential part of the program's leadership; and 4) certainty that the university can assist in improving the public schools only if it makes a significant and long-term commitment to do so.

Important features of the program include:

- It is a sharply focused effort with a well-defined approach confined to the public schools in New Haven.

- There is intellectual symmetry in the program; university faculty provide the major competence and initiatives in the area of subject matter and the follows drawn from the faculties of the New Haven middle schools and secondary schools provide the major competence and initiatives in the area of pedagogy. Topics for the seminars are generated by the secondary school teachers; content of the seminars is drawn from the university professors.

- There is unqualified commitment to the program by the New Haven public schools and by the top administration at Yale; this commitment has been enduring and all indications are that it will be for the long term--Yale has decided to seek a $4 million endowment to give the program a secure future. Both the New Haven schools and Yale see that they are pursuing their self-interest through participating in the Institute.

- Senior and prestigious Yale faculty are involved from a range of disciplines. Yale does not have a school or department of education and, in the view of one observer, this is a blessing. He states, "Without an intermediary buffer, softening, exaggerating, or explaining away the contrast of intellectual milieu between secondary education and higher education, the two groups of teachers (New Haven school teachers and Yale faculty) are free to explore for themselves the extent to which they share values and assumptions about their subject and its role in the development of children's minds and characters."

- Teacher participants in the Institute are designated as Institute Fellows. They are remunerated, each fellow receiving an honorarium on successful completion of the program. Fellows are full members of the Yale community; they are listed in the university director of faculty and staff; this has symbolic meaning in recognizing them as colleagues and practical value in making Yale resources readily accessible to them.

- The administration structure reflects the primary of teachers. Leadership is provided by a small group of teachers, designated as Institute Coordinators; the project has teacher coordinators in each participating school. Also, the program has had the same director since its inception in 1978, and he has guided the program with great skill, bridging the gap between the university and the community.

Conclusion

I have identified one topic within the general area of scientific and engineering talent that requires greater understanding, that is, the flow of the most talented students into graduate programs in the sciences, mathematics, and engineering. Existing data do not indicate that there is a problem in this area, but neither do they provide assurance that there is no problem. Because the most talented students are so critical to scientific and engineering advances, and because there are reasons to be concerned about the future supply of such talent, we would do well to understand more about the current supply and about the factors that influence the decisions of these students to pursue graduate education and research careers.

Second, I have identified a range of programs that can be considered to be at least, in part, a kind of scholar/practitioner network. All of these programs are considered to be successful. From this diverse set of successful networks, I have derived a list of principles for creating scholar/practitioner networks for the purposes of stimulating discussion.

- By definition, scholar/practitioner networks must include scholars and practitioners--and they must include the best scholars and the best practitioners to demonstrate that the activity is legitimate and to encourage broader participation from both communities. The teacher/practitioners must be included in meaningful ways and be given leadership and decision-making responsibilities.

- The network must involve the direct participation of senior officials with policy-making and decision-making responsibilities from the institutions in which the activities of interest take place--i.e., government agencies, schools, universities, museums, etc. In education, the translation of new knowledge and new programs into practice requires more than the commitment of individual scholars and practitioners; it requires institutional commitment throughout the multilayered education bureaucracy. Thus, participation by individuals who can commit their organizations is required.

- The subject addressed by the network--as, for example, the most capable youth in mathematics, science, and technology--must be viewed as high priority and intellectually challenging by all participants. Everyone must view the problem as worth solving; everyone must perceive that they will derive a benefit from participation in the network process and from reaching a solution to the problem. Self-interest unevenly distributed among the participants will result in the exploitation of one or more

groups and failure; self-interest evenly distributed among the participants is essential for success.

- Establish near-term and long-term objectives. Accomplishments in the near-term are essential to maintain the interest and commitment of all parties. The network should be established for the long-term.

- Cooperation and collaboration cost money, take time, and require perseverance. There must be an organizational structure and staff with the clear, ongoing responsibility for establishing and maintaining the network--it will not continue with "a momentum of its own." There must be ongoing financial support for the business of the network and for the organization and people who operate it. The challenge is how to do this without creating the reality or the perception of just adding layers of bureaucracy to the system.

- Flexibility--both organizational and financial--is required to respond to variations in conditions, in the nature of the problems, and in opportunities. The necessity to satisfy the many different participants in the network requires the ability to respond to a variety of demands and to take advantage of special opportunities when they arise.

- Any network is foremost a process, and success depends on the quality of interpersonal interactions and relationships. Skillful, imaginative, and delicate leadership is required to select the core participants in the network and to facilitate this intensely personal process. Delicacy is important because it is the core participants in the network and the problems they are addressing that must be the center of attention; the facilitating organization and individuals must find a way to exercise leadership but to remain in the background.

- The sponsoring organization(s) of the network, which also may be the home for the operating unit, must be held in the highest regard by all of the participating groups. This issue of quality runs throughout the principles. Establishing and operating a network is difficult; there are lots of reasons for it not working. The only hope for success is that the individuals and institutions involved in the core of the operation be the "opinion leaders" in their peer groups.

There is one feature of any network that is notably by its absence from the above list-the level at which it is organized, i.e., local, state, regional, or national. I find myself considering several different factors related to this question and unable to put forth a single principle. Therefore, I simply raise some of these factors as a basis for further discussion.

The success of the local models--the Urban Mathematics Collaboratives and the Yale-New Haven Teachers Institute--is compelling. Our educational system is grounded in state and local autonomy; local conditions vary; local problems vary; and the institutions and individuals who can best bring the practitioner and scholarly communities together also vary. Theodore R. Sizer, in evaluating the Yale-New Haven Teachers Institute, stated: "The arguments for the current scale

are powerful. All too few school 'reform' efforts to get the scale right; almost universally they are too ambitious . . . by remaining small, focused and uncomplicated, the Institute will serve its purpose admirably."

On the other hand, much activity in education is based on national models--for example, textbooks, teacher education, and much of testing. Furthermore, many of the educational reforms called for are national in scope--for example, curriculum reform, teacher rewards and working conditions, and increased attention to the most capable youth. The objectives of education are becoming less influenced by local conditions and more by national and even international needs. While comparisons and competitions among local schools will continue, we see an increase in comparisons of the U. S. with other countries, and we see the results of these international comparisons used as a basis for school and curricular reform. Finally, I think of the current situation in agriculture. With a long-standing focus on research and extension at the state and local levels, substantial improvements in agricultural productivity have been achieved. Now the system is criticized by some for giving insufficient attention to research areas, most notably biotechnology, that could have a profound national and long-term impact on agriculture.

In considering the local-national axis for scholar/practitioner networks, the answer is probably that both are required--local and national. And, to use a well-worn metaphor in this area, the goal is to weave the local networks into a national fabric that will cover local and national concerns in a balanced manner. The metaphor is well-worn, but the fabric is not. Although often proposed as an approach to the nation's educational needs, I do not think we have achieved it. The Mathematical Sciences Education Board is a recent attempt at such a combined, national-local approach. How do you think a "network of networks" could be established to address topics related to the most capable youth in mathematics, science, and technology?

Notes

1. The views expressed here are mine; they do not represent the views of the Research Roundtable Council nor of its sponsoring organizations, the National Academcy of Sciences, National Academy of Engineering, and Institute of Medicine.

2. Solmon, Lewis C. and La Porte, Midge A. (1986). The crisis of student quality in higher education. *Journal of Higher Education,* Vol. 57, No. 4, 370-392.

3. Goldberg, Frank and Koenigsknect, Roy A. (1985). The highest achievers: Post-baccalaureate Enrollment of Four Classes Between 1956 and 1981. Consortium on Financing Higher Education, Northwestern University.

4. Hartnett, Rodney T. (1985, March). *Trends in student quality in doctoral and professional education.* Rutgers, NJ: Rutgers University.

Attachment 1

Choice of Undergraduate Major
Data in Support of Figure 1

	1967		1975		1983	
	Enrollment Share	**Quality Share**	**Enrollment Share**	**Quality Share**	**Enrollment Share**	**Quality Share**
Biosciences	3.7	6.2	6.3	12.9	3.8	7.6
Engineering	9.5	10.0	7.9	13.3	11.7	19.2
Physical Sciences	7.2	21.3	3.8	11.5	2.6	7.1
	20.4	37.5	18.0	37.7	18.1	33.9

Source: Solmon, op. cit.

Attachment II

The change between 1981 and 1985 in the percentages of freshmen intending to major in various science and engineering disciplines who had A+/A/A- high-school grade averages.

The following increased by more than 10 percentage points:

Anthropology	+22
Botany	+20
Industrial Engineering	+16
Microbiology	+13
Chemistry	+12
Biology	+10

The proportion of top students in the following fields decreased by more than 10 percentage points:

Statistics	-24
Geography	-18
Astronomy	-16
Zoology	-16
Sociology	-15
Atmospheric Science	-12

The percent of students who graduated in various science and engineering majors who were top students (those in the 1981 freshman cohort who earned B+ or better averages in 1985).

The following majors had more than 40 percent of their students fall in this high-achiever category.

Astronomy	100%
Statistics	100
Anthropology	94
Biochemistry/Biophysics	64
Physics	62
Botany	47
Mathematics	45
Aeronautical/Astronomical Engineering	44
Chemistry	44
Biology	42
Chemical Engineering	41

Attachment II (continued)

The following majors had less than 40 percent fall in this high-achiever category:

Industrial Engineering	32%
Electrical Engineering	30
Zoology	28
History/Political Science	28
Psychology	27
Economics	23
Mechanical Engineering	23
Earth Science	21
Sociology	17
Microbiology/Bacteriol	7
Geography	7

As points of contrast, the comparable figure are:

Premedicine/dental/veterinarian	29%
Business	18

Persistence rates by field and field-switching patterns with A averages at the time of receipt of the bachelor's degree. Persistence rates for A students by field were:

Mathematics	87%
Physical Sciences	85
Engineering	74
Life/Environmental Science	68

Students with A averages defecting from science and engineering fields primarily took the following directions:

From Mathematics to Physical Science	13%
From Physical Science to Engineering	12
From Engineering to Physical Science and to Biological/Environmental Science	10 9
From Life/Environmental Science to Social Science (22%) and Business	5

Source: Holmstrom, Engin Inel. "Quality of Students in Sciences and Engineering: Change or Stability?" Draft report submitted to the National Academy of Sciences, August 31, 1987.

Attachment III

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

ROUNDTABLE COUNCIL MEMBERS

James D. Ebert
CHAIRMAN, Roundtable
Director, Chesapeake Bay Institute
The Johns Hopkins University

Orville G. Bentley
Assistant Secretary for Science and Education
U. S. Department of Agriculture

Joel S. Birnbaum
Vice President and General Manager - Information Technology Group
Hewlett-Packard Company

Erich Bloch
Director
National Science Foundation

Richard F. Celeste
Governor
State of Ohio

Marvin L. Cohen
Professor of Physics
Physics Department
University of California, Berkeley

William Danforth
Chancellor
Washington University

James F. Decker
Acting Director
Office of Energy Research
U. S. Department of Energy

William R. Graham
President's Science Advisor and Director, Office of Science and Technology Policy (OSTP)
Executive Office of the President

Kenneth H. Keller
President
University of Minnesota

Ronald L. Kerber
Deputy Under Secretary of Defense for Research and Advanced Technology
U.S. Department of Defense

John D. Macomber
Chairman
J. D. Macomber and Company

Frank Press (ex officio)
President
National Academy of Sciences

Nathan Rosenberg
Professor
Department of Economics
Stanford University

John E. Sawyer
President Emeritus
Andrew W. Mellon Foundation

Rudi Schmid
Professor of Medicine and Dean, School of Medicine
University of California

Howard A. Schneiderman
Senior Vice President for R&D
The Monsanto Company

Attachment III (continued)

Ben G. Streetman
Professor of Engineering
University of Texas at Austin

Samuel O. Thier (ex officio)
President
Institute of Medicine

Alvin W. Trivelpiece
Executive Officer
American Association for the
Advancement of Science

Thomas N. Urban
President and Chairman
Pioneer Hi-Bred International, Inc.

Robert M. White (ex officio)
President
National Academy of Engineering

Linda S. Wilson
Vice President for Research
University of Michigan

James B. Wyngaarden
Director
National Institutes of Health

Discussant Reaction: Creating Scholar/Practitioner Networks for the Most Capable Youth in Mathematics, Science and Technology

Raymond Hannapel

Don Phillips gave us some interesting examples of networks. His focus on the Mathematics Science Education Board (MSEB) is very interesting because it is an attempt by the Academy to draw in several partners. The Academy is making a long term commitment to providing national leadership in the reform of mathematics education in the United States. It is a very ambitious undertaking, but terribly necessary. Their efforts are certainly of interest to this conference, and indeed to the whole professional community interested in increasing the talent pool in mathematics.

Several of the collaborative efforts and networks that Dr. Phillips chose were aimed at the issue of mathematics or science or trying to improve the quality of the experience for all students. That's just the place to start if you are going to think about talent development. I worked with the National Science Board Commission on mathematics, science, and technology education that developed *Educating Americans for the 21st Century,* which was a long term plan for trying to address the issue of improving science and mathematics education at the precollege level, the elementary and secondary school level. It became very obvious when looking at all the evidence that the Commission looked at that the most important aspect was to increase the quality and the quantity of science and mathematics experiences for younger children. That's the place to start, and that was a good point to draw into this.

What I would like to focus on is the question that Dr. Phillips used to end his paper: How do you think a network of networks could be established to address topics related to the most capable youth in science, mathematics, and technology? I'd like us to think about that issue, but I'd like to rephrase it a bit: What kinds of networks could be established that would cultivate talent in youth in mathematics, science, and technology? What kind of networks would generate niches where interested young people would be provided both with exposure and experience to what I would like to call the 'culture of science'?

When we try and juggle with these questions I would submit that if we're really concerned with the culture of science, and here I mean mathematics as well, we need to think about providing experiences for youth in a locale where things are going on. But because of the nature of the culture of science, not just local, or just national, it's giving students access to an international kind of subculture.

What do I mean by that? Let me back off just a minute and raise a couple of questions about the nature of that experience and what it might be before I go into some suggestions I have for a network of networks, and address Dr. Phillips' question. I found a provocative paper by Ken Bolding very instructive here, and I'd like to run through some of its main points. This was the American Association for the Advancement of Science (AAAS) Presidential address in 1980 (*Science*, January 1981). Its called "Science: Our Common Heritage." Bolding does an historical and logical analysis of the nature of science, how it developed, and how it has become a keystone of western culture. He attempted to do an analysis of the value of the belief structure of that subculture.

Bolding noted that the most important value in the enterprise of the subculture of science is the high value placed on curiosity. The value of the good question as opposed to having all the right answers. The value of the good question combines with the high value placed on the interplay between imagination and reality. There's an element of fantasy and imagination coupled with logical reasoning that essentially invents descriptions, theories, whatever. But fantasy and imagination are always anchored in the test of reality in the real world, and that's another important attribute.

Bolding makes another point about veracity, and how important veracity is to this whole enterprise: recognizing your data for what it is. The quickest way to get drummed out of a court is to falsify results. It's very critical being able to depend on another person's data, recording it faithfully and accurately. He makes an interesting point about something that developed in this subculture that was not very pervasive in the 1500's, the 1600's: the legitimacy of error. Trial and error is the keystone of reality testing, so error is very important. You learn a lot from making errors. Finally, he talks about the development of the last attribute and that is the replacement of coercion with persuasion. That was a source of trouble very early on between science and the Establishment. Something important to think about as we think about networks is what will foster talented youth in science and math, because doing science, doing mathematics is really a generative process--it's creating human knowledge, inventing new anxious.

Very often, academic experience, and this is true not only in elementary and secondary schools, but in colleges and universities, provides a preponderance of knowledge acquisition for students. It's important to keep our focus on the issue of *making* mathematics and *making* science as a key experience for young people, when we're concerned in developing talent. I believe that we ought to do this for all our students, but I think it's especially important to be clear about this with people who are going to do science and mathematics in the society.

With that as a little bit of background and with some of the criteria that Don Phillips ended with in his paper, I'd like to tell you about a new initiative at NSF which is really a resurrection of an old and successful program, the Young Scholars Program, that was just initiated this year.

It took several years to persuade the Office of Management and Budget that the Young Scholars Program was important and to allow the NSF to get back into this activity. Some of you may remember something called Students Science Training (SST) Program that was around for 20 years at NSF. The idea of the program is to establish a number of new projects, and also to establish programs that persisted in the absence of support of NSF to make them better. I have an example of such a program. I don't know how many of you know Arnold Ross, who's a premiere mathematician, highly regarded at Ohio State. Arnold had been working with high school students for several years with support from the this SST program. Arnold's and several other programs have persisted when support was cut off in 1981 from NSF, mainly because the whole class in engineering education program was curtailed. There is an opportunity now for these programs to augment what they're doing, to provide scholarship activities to students who can't afford the tuition, and some of them are very expensive as you know--

anywhere from $1,200 to $1,800 depending on the length and nature of the experience.

The program also provides support for several new activities, and allows the opportunity not only for scholars and researchers working with young students, but also for scholars working with teachers and students. So the funded group can be teachers and students. There are all kinds of flexibility in participating in the program. But the key features of these programs are really the *nature* of the activity. Let me read something from the program notes, some advice we give to proposers:

> Proposers should keep in mind that students learn science best by practicing science, that is, by exercising the natural curiosity and engaging in scientific research and discovery. Projects may consist of any combination of activities involving instruction, problem solving, and exposure to the research environment and research methods that are appropriate for the target age group and the discipline focus. Activities should be strong, be participatory, be intellectually challenging and promote positive interaction among the students and the staff. Proposers are encouraged to design innovative methods and approachers and should strive for a balance between lecture, laboratory, field, and research experiences. Young Scholar Projects are not intended to provide course work primarily designed to prepare students for Advanced Placement, or to duplicate regular college courses.

The intention here is to provide a range of disciplinary opportunities in locations at some of the top university research laboratories, field stations, and industrial and government laboratories for our best students. A second intention is to establish a network of collaboration among the project directors. That will be done through regular meetings of the actual project directors. There's additional information in the program note. I won't go into detail, but the important components should include follow-up activities with these young people, as well as with career exposure.

Another activity that is up and running at NSF is a program in the area of teacher enhancement called Science and Mathematics Networks. This program is specifically targeted at providing the kinds of support to projects with the attributes Phillips was mentioning: where there is a sharing of responsibility and of the benefits of collaboration. One example of a project is referred to as the Triangle Coalition. It's a coalition of business, industry, science and engineering research, schools and academic scientists and mathematicians. Some of the initial projects have been the promotion and facilitation of quality science experience in elementary schools. There is a network of these people supported by the Networks Program at NSF.

There was also a program announcement for business partnerships and soon there will be an announcement of awards from that solicitation. Those are a variety of collaborations between community groups, business, industry, school board, community leaders, schools and universities, or other agents such as science museums or field stations.

I should tell you a little bit about the level of funding, especially the Young Scholars Program. The program is being funded at a little over $3.5 million this year. In the next fiscal year, that's the budget that's being considered by the Congress, that's due to double to $7 million. It's a very important priority of the National Science Foundation. It also enjoys the support of Eric Bloch who is the director in the National Science Board. It was solely due to two years of lobbying the Office of Management and Budget by Eric Bloch that program was started. So, those are some examples from NSF, and I would just end by saying let's consider some others. I think Dr. Phillips' question is a good question.

Discussant Reaction: Creating Scholar/Practitioner Networks for the Most Capable Youth in Mathematics, Science and Technology

Gregory A. Kimble

Because of what highly talented people potentially can do to improve the human condition, the nourishment and preservation of their talent is a matter of great importance. Although people with other specialties may make equal contributions, the support of those with skills in science and mathematics is particularly urgent in this age of high technology. One measure of success in the achievement of this goal is the number of people who receive the Ph.D. degree in some branch of science or mathematics.

Over the last 20 years, in American universities there has been a general increase in the number of individuals who receive their Ph.D.'s in science. For a moment one might conclude that we are doing very well. Details of the data reveal, however, that there are reasons to draw conclusions with more caution than that. In the physical sciences, the number of Ph.D.'s has bucked the trend and is down by 20 percent. Meanwhile, the number of Ph.D.'s in the applied field, Engineering, has gone up by something like the same amount. In psychology, there is a very much exaggerated version of this same pattern. Since 1967, the number of Ph.D.'s in research/academic psychology has declined by 20 percent, while the number awarded to health service providers has trebled.

The reason for the pattern just described is economic. People are preparing themselves for occupations that are practical, well paid and available. Partly as a result of these incentive factors, science is falling behind in the number of undergraduate majors that it attracts. In particular, the best and brightest students are staying away in droves. The other causal factor that is keeping students out of science and mathematics majors is inadequate preparation. Too many of them find out in the first college course they take in science that they lack the skills that are taken as assumed prerequisites. In recent years, American education in science and mathematics at the secondary level has been lagging. It has now deteriorated to the point where the United States has the status of a disadvantaged nation in this regard.

Structures called "scholar/practitioner networks"--it would be more accurate to call them "scholar/administrator/practitioner networks"--have been created as a means of dealing with the shortcomings of science education in America. These networks, made up of people who are committed to the program, able to work together and blessed with appropriate expertise, undertake a wide range of activities and support a wide variety of projects aimed at improving the situation of science in our country. They encourage research, support symposia and workshops, offer fellowships and internships, establish policy and priorities, and facilitate communication through meetings and publications.

As short-term goals, these accomplishments are to be applauded. It is unclear, however, whether they are having any impact on the problem at its source, the reluctance of society to provide adequate support for scientific education and research.

Figure 1

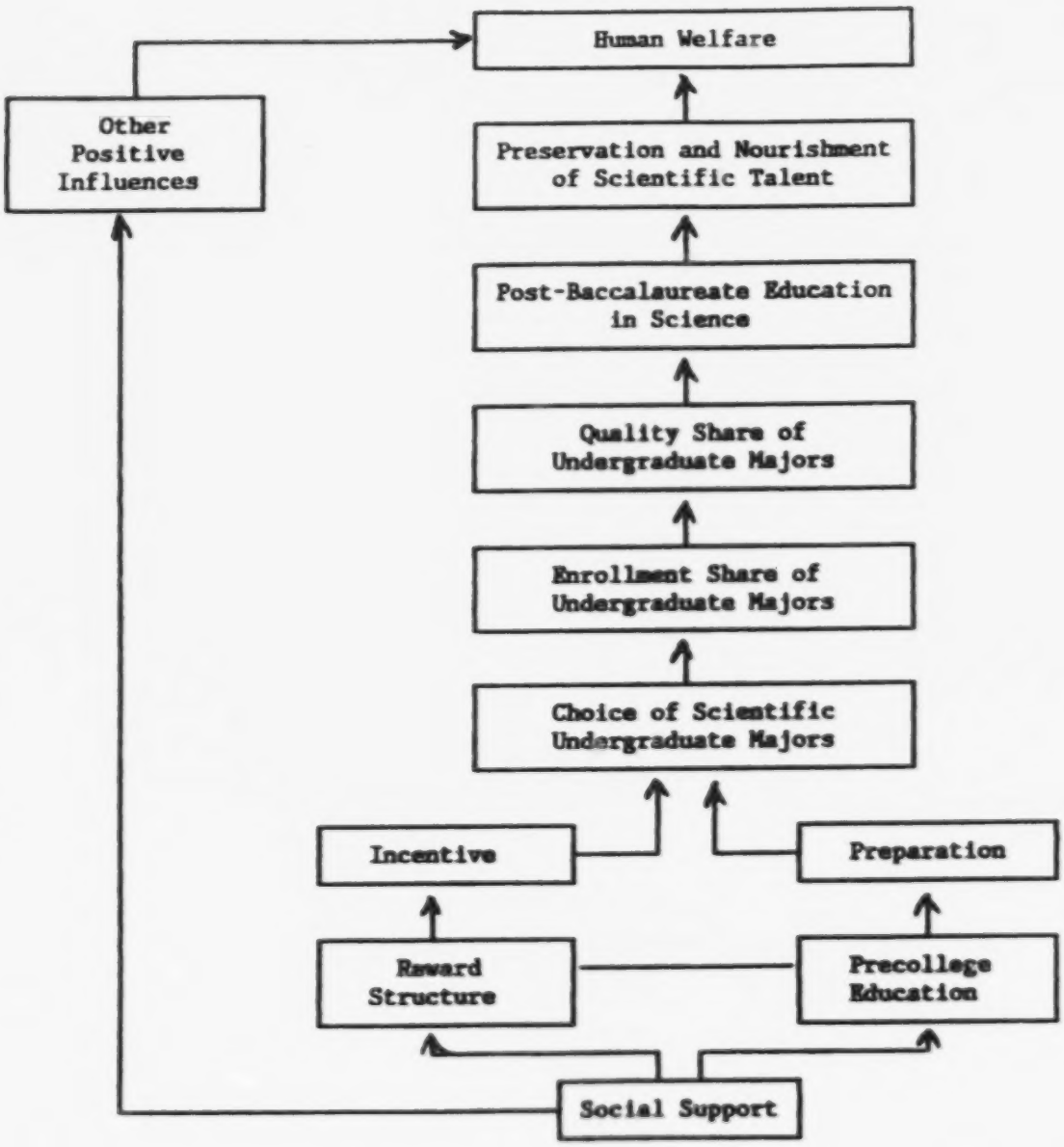
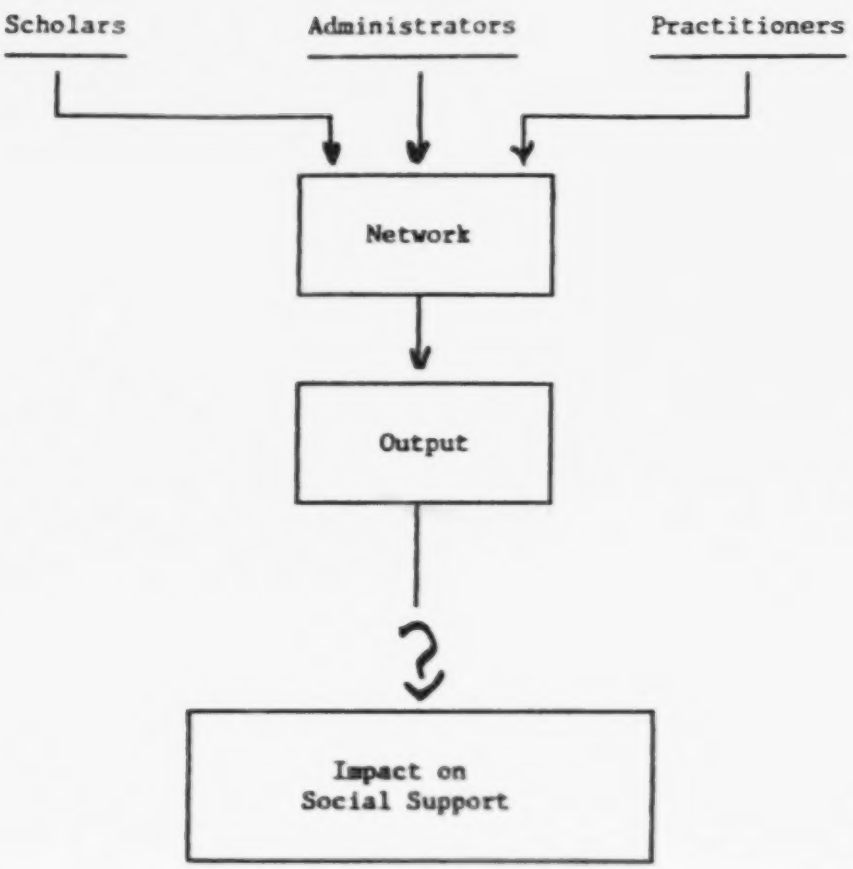

Human Welfare
Other Positive Influences
Preservation and Nourishment of Scientific Talent
Post-Baccalaureate Education in Science
Quality Share of Undergraduate Majors
Enrollment Share of Undergraduate Majors
Choice of Scientific Undergraduate Majors
Incentive
Preparation
Reward Structure
Precollege Education
Social Support

Figure 2


Scholars
Administrators
Practitioners
Network
Output
?
Impact on
Social Support